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UNITED STATES PATENT APPLICATION

for

NON-STICK DETECTION METHOD AND MECHANISM FOR ARRAY MOLDED  
LAMINATE PACKAGES

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## NON-STICK DETECTION METHOD AND MECHANISM FOR ARRAY MOLDED LAMINATE PACKAGES

### FIELD OF THE INVENTION

5           Embodiments of the present invention relate to the field of integrated circuit packaging and testing.

### BACKGROUND OF THE INVENTION

10           Manufacturing methods for integrated circuits have kept pace of, and in many cases enable, developments in the integrated circuits themselves. The ever smaller feature architecture within IC's has been accompanied by the technology that allows ever smaller packaging of the IC chips. Size, time and cost of IC production have all continued to shrink at tremendous rates.

15           Testing techniques associated with the various stages of IC packaging has been pressed to keep up with developments in the other areas of production. As new methods of connecting IC's into the surrounding electronic world have emerged, some older testing regimens have been a restriction on some developments.

20           Among the many packaging techniques that has emerged in recent years is the ball grid array (BGA). An improvement on earlier surface mount technology, BGA has allowed orders of magnitude

improvements in speed, miniaturization and reliability of packaged IC's.

In BGA packaging, the array of solder pads that lends the name to the technique are typically mounted on one surface of a tiny  
5 printed circuit board (PCB), not much larger than the IC die itself, and made of a very thin substrate. The IC die is bonded and wired to connections on the opposite side of the small PCB using microscopic connections.

Typically, the small BGA PCB's are constructed in relatively  
10 large, array molded, laminate substrate sheets. By obviating the need for the long lead fingers of the prior lead frame array associated with previous surface mount technology, BGA packaging allows relatively dense arrays of units in process. The IC's are each bonded to the appropriate positions on the laminate substrate while  
15 the small BGA PCB's are still attached to each other. After bonding the dies to the substrate traces and testing the connections, the sheets are generally separated into individual units for functional testing.

Commonly, in this process in which multiple BGA units occupy  
20 the same laminate substrate strip, the individual traces on each of

the units are connected to a common bus line (109, Figure 1A) in order to allow an electrolytic plating process for Gold/Nickel plating, in an electro-plated substrate. These bus lines are eventually connected to the mold gate. This is called a "standard bus design" type packaging substrate.

During wire-bonding of such substrates, wire non-stick-on-pad (NSOP) and non-stick-on-lead (NSOL) conditions can be detected to avoid wire bond failures in assembly. This is done by using the electrical circuit as shown in conventional art Figure 1A. The bus enabled circuit is formed after bonding IC 102 to BGA substrate 101 and wire-bonding first wire connection 106. The circuit closure is made through the gold wire in the spool, 105, the wire on the bond pad 106, to the lead finger 107 using the first wirebond 108, to bus-line 109 from lead fingers and finally to the mold gate 110.

The mold gate is grounded to the wire bond clamp. Using this circuit, if there is a bad bond on either the bond pad or lead finger, the circuit is affected, and the bond's quality can be easily measured electrically. Similar technology is used in leadframe based assembly, where the die attach pad is grounded to the wire bond clamp, through the leadframe, and is used for Non stick detection (NSD).

Since all the individual IC dies in a standard bus design substrate are connected electrically to each other via the bus lines, they cannot be tested, or burnt-in, in strip form and must be separated before being handled and tested as individual units. Also,

5 since the first circuit is not completed until the first bond is completed on both ball pad side and lead finger side, the first ball bond NSOP detection has to be skipped in the wire-bond test step. For all successive bonds, this first bond serves as the electrical connection between the silicon and the lead fingers for grounding to  
10 the mold gate. If a no-bus type substrate design is used, in order to allow for in-strip testing, there is no NSD capability since the electrical circuit is not completed back to the mold gate in the absence of the bus-line connection. Conventional Art Figure 1B illustrates a no-bus design. Lead fingers 107 are isolated from each  
15 other and from mold gate grounding 110. The result is an open circuit 105 and an inability to check for proper sticking in connection wire 106.

The current art, then, is disadvantageous because the prevalent and method of NSD requires that lead fingers be grounded which  
20 prohibits in-strip functional testing and burn-in of the packaged ICs.

SUMMARY OF THE INVENTION

Presented herein is a method for performing non-stick detection in a BGA packaging substrate array strip that does not require a bus connecting all leads and pads together. Furthermore, the testing method allows the assembled BGA packages to be functionally tested while still in the array strip.

More specifically, embodiments of the present invention relate to a method and mechanism for testing wire bonds in an integrated circuit package. The method comprises bonding an integrated circuit silicon die to a package substrate. Next, wire connections are formed between pads in the integrated circuit silicon die and contact leads in the package substrate and testing each of the wire connections in order to detect non-stick failures using electrical continuity provided by the integrated circuit silicon die substrate. Electrical continuity is provided through dedicated pads in the package substrate that contact the underside of the silicon die substrate. The dedicated contact pads in each package substrate of the molded laminate array are connected to each other and to the mold gate. The continuity thus provided allows a non-stick-on-pad test by ensuring continuity between the wire spool through the die to the mold gate. Non-stick-on-lead check then looks for an open circuit between the wire spool and the mold gate which

indicates a successful wire bond to the lead and associated separation from the wire feed capillary. The IC contact pads and leads in the package substrate are electrically isolated in order to allow functional testing and burn-in while the packaged integrated circuits are still in  
5 the laminate substrate array.

These and other objects and advantages of the present invention will become obvious to those of ordinary skill in the art after having read the following detailed description of the preferred embodiments which are illustrated in the various drawing figures.

## BRIEF DESCRIPTION OF THE DRAWINGS

The operation and components of this invention can be best visualized by reference to the drawings.

Conventional Art Figure 1A illustrates conventional NSD  
5 testing in a bus-connected array.

Conventional Art Figure 1B illustrates a failure of  
conventional NSD testing in a non-bus-connected array.

Figure 2 illustrates array molded laminate substrates with  
NSD pad and bus in accordance with one embodiment of the present  
10 invention.

Figure 3 illustrates non-stick on pad (NSOP) detection in  
accordance with one embodiment of the present invention.

Figure 4 illustrates non-stick on lead (NSOL) detection in  
accordance with one embodiment of the present invention.

15 Figure 5 illustrates a non-stick detection method in flowchart  
form.



DETAILED DESCRIPTION

Reference will now be made in detail to the preferred  
embodiments of the invention, examples of which are illustrated in  
the accompanying drawings. While the invention will be described in  
5 conjunction with the preferred embodiments, it will be understood  
that they are not intended to limit the invention to these  
embodiments. On the contrary, the invention is intended to cover  
alternatives, modifications and equivalents, which may be included  
within the spirit and scope of the invention as defined by the  
10 appended claims. Furthermore, in the following detailed description  
of the present invention, numerous specific details are set forth in  
order to provide a thorough understanding of the present invention.  
However, it will be obvious to one of ordinary skill in the art that  
the present invention may be practiced without these specific  
15 details. In other instances, well-known methods, procedures,  
components, and circuits have not been described in detail so as not  
to unnecessarily obscure aspects of the present invention. At times,  
concepts disclosed in this embodiment of the present invention will  
be made more readily apparent by reference to the Figures.

20 Embodiments of the present invention discussed herein relate  
to testing methods in the packaging process of integrated circuit

production. In this embodiment, the electrical path for testing the wire bonding of each unit is completed through the die backside, connecting to a special metal pad under the die, to be used only for NSD. In this implementation, the die backside is grounded to a

5 special NSD trace on the substrate die paddle area. This trace metal land is not covered by the solder mask coating, so that there is electrical contact between the die backside and this trace land via the conductive die attach material. Note that, being uncoated, the metal land is easily etched back subsequent to NSD.

10 These special NSD traces are connected to a bus line and shorted back to the mold gate. The traces can be connected to the bus line used for plating the lead fingers or an additional bus line. These bus lines can be on either the top or bottom metal layer of the substrate. In case of connection using the bottom metal layer, the  
15 traces are connected to traces on the bottom of the substrate using drilled and plated vias. The bus-lines on the bottom layer are then connected back to the mold gate on the top layer using another plated through hole via under the mold gate.

Figure 2 illustrates a possible location for the dedicated NSD  
20 contact pads 220 in packaging substrates in a molded laminate array. Dedicated pads 220 are shown connected by traces 215 to

NSD bus 210. Bus 210 connects NSD pads in other substrates in the substrate array as well. Note specifically that lead fingers 107 are not connected to each other nor to mold gate bus 110, making Figure 2 an illustration of a no-bus design array.

5 In the case of a "bus design," there can be two sets of bus lines, one used in the electrolytic plating of traces connected to the lead fingers, and another for bus-connecting the special NSD traces under the die. This allows selectively etching back the lead finger plating bus lines, without etching back the NSD trace bus line, to  
10 subsequently achieve a "no-bus" design.

In both bus and no-bus cases, this embodiment of the present invention allows a first ball bond NSD since the electrical circuit is complete through the gold wire in spool, the wire in the capillary, the die silicon, the electrically conductive die attach material, the  
15 non-stick detection trace under die, the bus line and, finally, the mold gate, which is grounded.

The circuit connection for NSD is illustrated in Figure 3. Here, test circuit 105 is shown completed during NSOP testing. Wire bond 106 has been attached to a pad on IC die 102 which is bonded using  
20 bonding epoxy 212 to packaging substrate 101. Continuity to

dedicated NSD pad 220 through the substrate silicon of die 102 is shown at 221. NSD pad 220 is connected via a trace 215 in a routing layer in substrate 101 to NSD bus line 210 and then to ground. Non-stick would be indicated by an open circuit 105.

5 Similarly, Figure 4 illustrates NSOL testing. Here testing indicates a stick failure when circuit 105 is completed through the bonding wire. Wire bonds are made, in this embodiment, by attaching the die pad end first, checking NSOP, then bonding the lead end. A successful bonding results in separation of the wire from the wire  
10 feed capillary 104. If the wire bonding fails to stick to the lead contact pad, then that failure is indicated by circuit 105 remaining closed. A successful stick would be indicated by an open circuit.

In this implementation of this embodiment of the present invention there are two of the dedicated NSD traces on each die  
15 attach area, both connected to the bus lines and to each other. This could allow an electrical path between bus lines of adjacent die paddle units; even when the die is absent. Since substrate production typically produces less than 100% yields, it is common to get some reject spots on the substrate where a die attachment is  
20 skipped. If the two traces are not connected to each other, then a

conductive path through the die attach material between them would be necessary.

Implementations of this embodiment of the present invention can also support NSD in processes using non-conductive die attach paste. In such a case, an implementation could be modified in the following manner. Any one of the lead fingers of each die paddle unit can be shorted and grounded to the mold gate, the lead finger to be used being selected based on the functionality of that lead finger. A common choice would be a ground pin finger.

During wire bonding, the first ball bond NSOP test would initially be skipped and the first wire bond to the grounded lead finger would be used as the electrical circuit completion for NSD of all the other wires, the continuity for which would an ohmic connection through the die material. This implementation would allow for etch-back of substrates in applications that use non-conductive die attach material as well. A wire bonder could be programmed to return to and check the first ball-bond NSOP at a later stage in the process. In most cases the ground pin lead finger can be used as the pin shorted to the mold gate for NSD.

This embodiment of the present invention allows true NSD for both NSOP and NSOL on all BGA packages, irrespective of the plating bus bar design, or fabrication methods, for every wire bond. This embodiment enables the capability of testing BGA units in strip form, as well as burn-in of the units in strip form. The cost and time savings of enabling bulk handling in these processes while still attached in strip form should be readily apparent. The savings would include reducing the test and burn-in costs by eliminating package-dimension-specific test sockets, burn-in sockets and boards.

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10 Process cycle time as well as costs related to package changeover can be eliminated using this embodiment.

Plastic BGA packages, in larger package sizes, can use a gold plated die attach paddle under the die as a grounding for NSD in this embodiment. However this is possible only if routing for the BGA contact pads does not use this space. Smaller BGA's, often referred to as Fine pitch BGA (FBGA) use the area under the die for trace routing and a die attach paddle implementation must take routing into account.

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Figure 5 illustrates the NSD method described herein in flowchart form. Method 500 starts by bonding the IC die to the packaging substrate, 510, then commencing the formation of wire

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bonding, 520. After bonding the connection wire to the IC's circuit contact pad, electrical continuity is checked, 530, from the wire spool through the wire feed capillary, the circuit contact pad, the IC die's silicon substrate, the dedicated NSD contact pads on the packaging substrate, the grounding line traces to the mold gate. If continuity does not exist 540 then a non-stick failure is assumed and the bond is redone, 550. If continuity does exist, there is no non-stick failure. The wire is then bonded at the lead contact pad on the packaging substrate, 560, and, if properly bonded, separates from the wire feed capillary. Then another continuity check is made, 570. If there is continuity at this point, 580, then the wire has failed to stick and a non-stick-on-lead failure is detected. The bond is reattempted, 590. If there is no continuity, then a non-stick is not detected and the process moves on, 599.

15       A new method for implementing non-stick detection for array-molded laminate packages without a plating bus has been described. The foregoing descriptions of specific embodiments of the present invention have been presented for purposes of illustration and description. They are not intended to be exhaustive or to limit the invention to the precise forms disclosed, and obviously many  
20       modifications and variations are possible in light of the above

teaching. The embodiments were chosen and described in order to best explain the principles of the invention and its practical application, to thereby enable others skilled in the art to best utilize the invention and various embodiments with various

- 5 modifications as are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the Claims appended hereto and their equivalents.

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